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STUDIES OF IONOSPHERIC PLASMA ELECTRODYNAMICS

R.A. Heelis

University of Texas at Dallas
William B. Hanson Center for Space Science
P.O. Box 830688, MS FO 22
Richardson, TX 75083-0688

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William S. Borer
Contract Manager

Frank A. Marcos, Acting Chief
Ionospheric Models Branch

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Roderick A. Heelis

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William B. Hanson Center for Space Sciences
University of Texas at Dallas
P.O. Box 830688 M/S FO22
Richardson, TX 75083-0688

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During this funding period we have examined in some detail the electromagnetic energy exchange between the ionosphere and the magnetosphere. In addition to this extensive analysis we have also begun a study of global equatorial electric field as seen in satellite data with a view to determining any differences between longitudinally distributed data and that given at a fixed ground-based site. These studies both have relevance to the development of global ionospheric specification models. At low latitude the E x B drift pattern is fundamental in determining the behavior of the F-region plasma and at high latitudes methods to represent the effects of magnetosphere-ionosphere coupling are esssential.

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STUDIES OF IONOSPHERIC PLASMA ELECTRODYNAMICS

Introduction

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1. The Global Distribution of Poynting Flux

An accurate determination of the Poynting flux and its variations in space is an extremely useful parameter with which to specify the effectiveness of ionosphere-magnetosphere coupling. It does not require assumptions about field-aligned current geometries that are used to specify field-aligned current densities from measurements of the magnetic field. Nor does it require assumptions about the nature of the dissipation in the ionosphere as are used in determining Joule heating rates. Rather, it is directly measured by the magnetic and electric field. The problem lies in accurate specification of the absolute magnitudes of these quantities.

Inspection of the data set from the Dynamics Explorer satellite shows that a significant effort must be taken to establish the correct baseline for measurements of the magnetic field perturbation. Very small uncertainties in the satellite inertial attitude produce continuously varying baselines that need to be removed from the data. After extensive analysis we have developed an algorithm for extracting the baselines from almost all the data. Figure 1 shows the resulting measurements of magnetic field and ion drift velocities that are used to derive the field-aligned component of the Poynting vector. With reasonable assumptions about steady state conditions, this component of the Poynting vector is equal to the energy dissipation rate in the volume below the satellite. Inspection of this and other data shows that under normal circumstances the Poynting vector is always directed downward into the ionosphere. The energy is deposited between the large scale field-aligned currents and in the summer hemisphere about equal deposition rates occur in the auroral zones and in the polar cap. During the winter the deposition rates in the polar cap are reduced significantly.

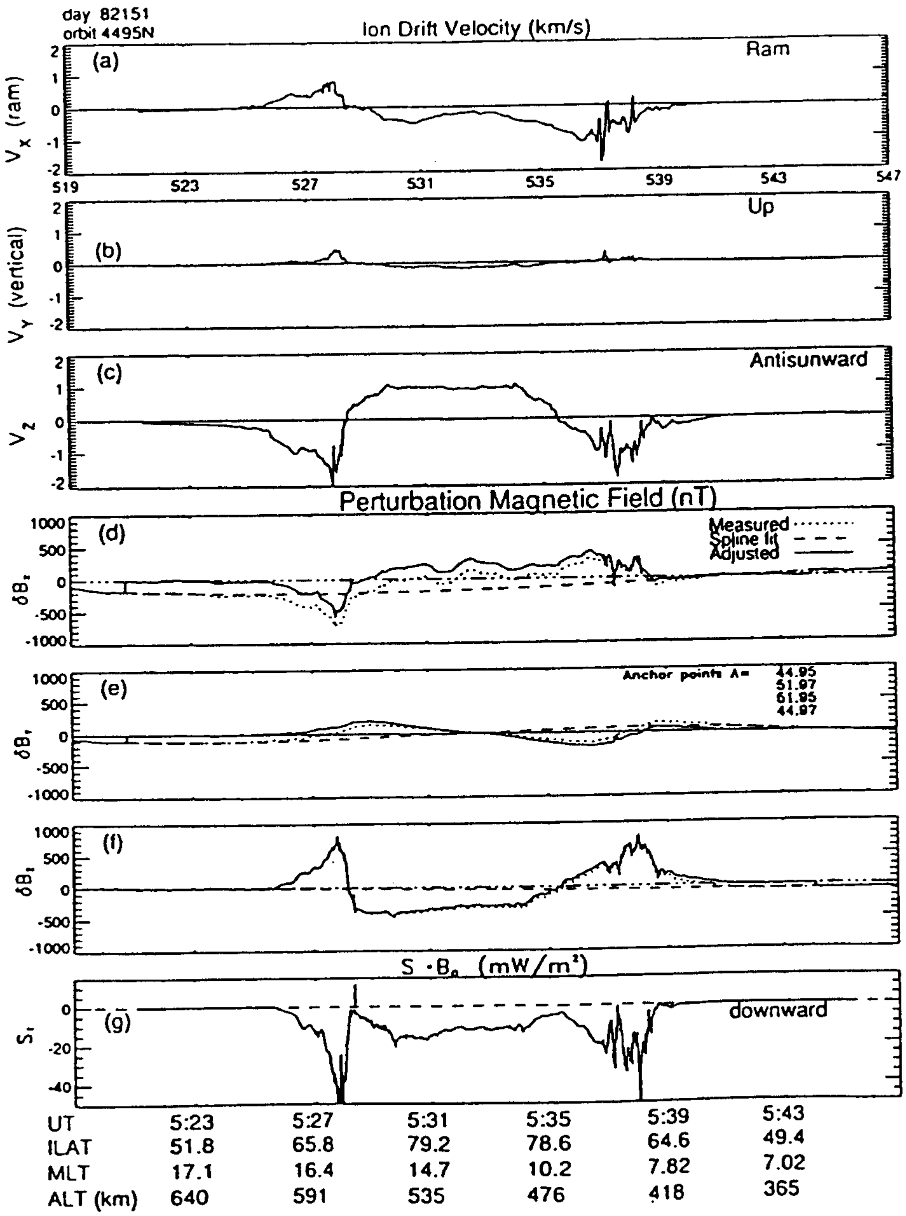

Figure 1. Component field measurements, analysis and derived Poynting flux for a high latitude pass of Dynamics Explorer over the summer pole.

We have searched specifically for regions in which the Poynting flux is directed away from the ionosphere, Such regions denote a dynamo action in the ionosphere and perhaps an electrical disconnect between the ionosphere and magnetosphere. Such regions are indeed observed but occur over small spatial extents that appear to be almost randomly distributed over the high latitude region. They are most frequent during times of northward IMF when electrical connection the solar wind is weakest and the previously imposed circulation in the thermosphere may act as a dynamo. For sensible values of the wind velocity we do not expect the upward Poynting flux to have values exceeding 10 mWm-2

2. Equatorial Ion Drifts from Atmosphere Explorer.

The ion drift meter data obtained from AE-E exhibit a great deal of variability. The average drift pattern shows a noticeable seasonal and solar cycle dependence. The daytime upward drifts are largely independent of solar flux while the evening pre-reversal enhancement shows a large increases from solar minimum to solar maximum. During 1978 and 1979 observations indicate that a longitudinal variation in plasma drifts is dependent on season. At equinox almost no longitudinal variation is seen. In particular the evening reversal time and pre-reversal enhancement do not seem to change with longitude. However in the June solstice rather large longitude effects are evident in the daytime drift patterns, the evening reversal times and the pre-reversal enhancement. Figure 2 shows a summary of the drift patterns derived from this data during for different seasons and longitudes.

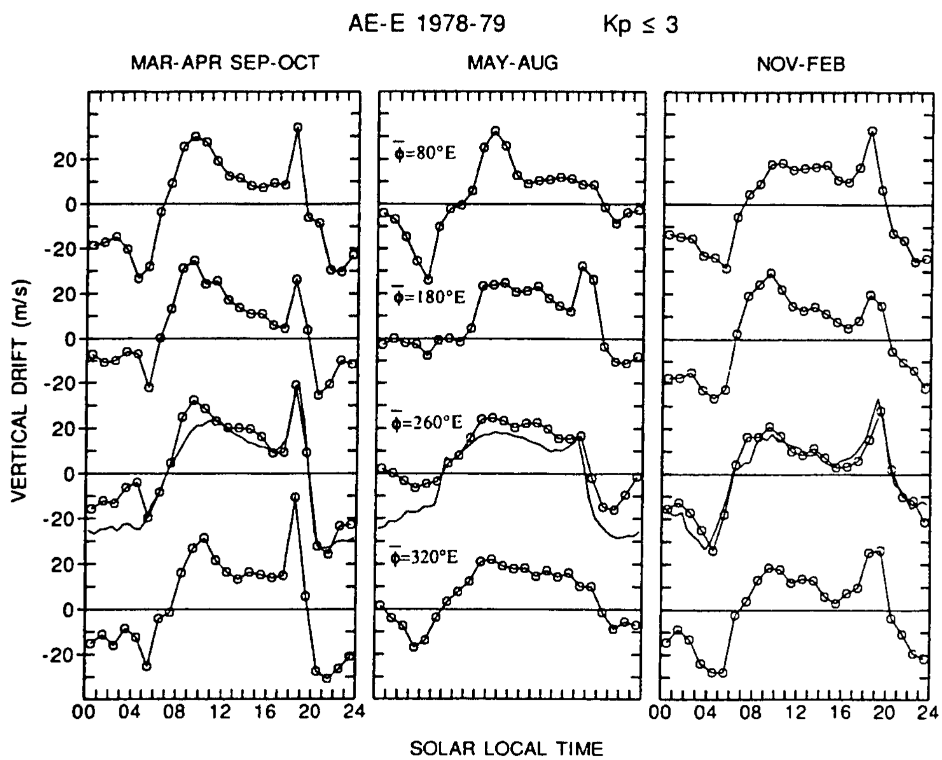

Figure 2. Season and Longitude variations seen in vertical ion drifts observed by AE-E.

These data are generally consistent with results from the Jicamarca radar in the appropriate longitude region. However a differing evening reversal time and associated pre-reversal enhancement could produce longitude variations in the observed F-region densities. This data set is insufficient to resolve all the variations that are apparent and points to the need for a more extensive satellite and ground based data set to be accumulated.

Publications

The work described above has been systematically published in the leading journals in our field. Titles and abstracts of this published work are given below.

Field-aligned Poynting flux observations in the high-latitude ionosphere

J. B. Gary, R. A. Heelis, and W. B. Hanson

Center for Space Sciences, Physics Programs, University of Texas at Dallas, Richardson

J. A. Slavin

Laboratory for Extraterrestrial Physics, NASA Goddard Space Flight Center, Greenbelt, Maryland

Abstract. We have used data from Dynamics Explorer 2 to investigate the rate of conversion of electromagnetic energy into both thermal and bulk flow particle kinetic energy in the high-latitude ionosphere. The flux tube integrated conversion rate E·J can be determined from spacecraft measurements of the electric and magnetic field vectors by deriving the field-aligned Poynting flux, $S_{||}=S\cdot\hat{B}_o$, where $\hat{B}_o$ is in the direction of the geomagnetic field. Determination of the Poynting flux from satellite observations is critically dependent upon the establishment of accurate values of the fields and is especially sensitive to errors in the baseline (unperturbed) geomagnetic field. We discuss our treatment of the data in some detail, particularly in regard to systematically correcting the measured magnetic field to account for attitude changes and model deficiencies. $S_{||}$ can be used to identify the relative strengths of the magnetosphere and thermospheric winds as energy drivers and we present observations demonstrating the dominance of each of these. Dominance of the magnetospheric driver is indicated by $S_{||}$ directed into the ionosphere. Electromagnetic energy is delivered to and dissipated within the region. Dominance of the neutral wind requires that the conductivity weighted neutral wind speed in the direction of the ion drift be larger than the ion drift, resulting in observations of an upward directed Poynting flux. Electromagnetic energy is generated within the ionospheric region in this case. We also present observations of a case where the neutral atmosphere motion may be reaching a state of sustained bulk flow velocity as evidenced by very small Poynting flux in the presence of large electric fields.

Summary of field-aligned Poynting flux observations from DE 2

J. B. Gary [1] and R. A. Heelis

University of Texas at Dallas, Richardson

J. P. Thayer

SRI International, Menlo Park, California

Abstract. Using DE 2 data of ion drift velocities and magnetic fields, we have calculated the field-aligned Poynting flux ($S_{\parallel}$) for 576 orbits over the satellite lifetime. This is the first application over an extended data set of Poynting flux observations from in situ measurements. The data has been sorted by interplanetary magnetic field conditions (northward or southward IMF) and geomagnetic activity (Kp$\leq$3 and Kp $>$3) and binned by invariant latitude and magnetic local time. Our general results may be summarized as 1) the averaged $S_{\parallel}$ is everywhere directed into the ionosphere, indicating that electric fields of magnetospheric origin generally dominate, and 2) the distribution of $S_{\parallel}$ for southward IMF can be well explained in terms of an average two cell convection pattern, while for northward IMF a multiple cell convection pattern may be inferred. We have addressed the interesting question of the distribution of upward Poynting flux by binning only upward observations and found that average upward Poynting flux of less than 3 mW/m^2 may occur anywhere across the high latitude ionosphere. We have also observed a region at high latitudes in the predawn sector where the average upward Poynting flux is of significant size and occurrence frequency during southward IMF and high Kp conditions.

Global equatorial ionospheric vertical plasma drifts measured by the AE-E satellite

B. G. Fejer and E. R. de Paula[1]
Center for Atmospheric and Space Sciences, Utah State University, Logan

R. A. Heelis and W. B. Hanson[2]
Center for Space Sciences, University of Texas at Dallas, Richardson

Abstract. Ion drift meter observations from the Atmosphere Explorer E satellite during the period of January 1977 to December 1979 are used to study the dependence of equatorial (dip latitudes ≤ 7.5°) *F* region vertical plasma drifts (east-west electric fields) on solar activity, season, and longitude. The satellite-observed ion drifts show large day-to-day and seasonal variations. Solar cycle effects are most pronounced near the dusk sector with a large increase of the prereversal velocity enhancement from solar minimum to maximum. The diurnal, seasonal, and solar cycle dependence of the longitudinally averaged drifts are consistent with results from the Jicamarca radar except near the June solstice when the AE-E nighttime downward velocities are significantly smaller than those observed by the radar. Pronounced presunrise downward drift enhancements are often observed over a large longitudinal range but not in the Peruvian equatorial region. The satellite data indicate that longitudinal variations are largest near the June solstice, particularly near dawn and dusk but are virtually absent during equinox. The longitudinal dependence of the AE-E vertical drifts is consistent with results from ionosonde data. These measurements were also used to develop a description of equatorial *F* region vertical drifts in four longitudinal sectors.